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SOME NOTES ON READINGS AT KEW OBSERVATORY OF THE GORCZYNSKI PYRHELIOMETER, THE SUNSHINE RECORDER and THE BLACK BULB THERMOMETER

By H. L. WRIGHT, M.A.

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SOME NOTES ON READINGS AT KEW OBSERVATORY OF THE GORCZYNSKI PYRHELIOMETER, THE SUNSHINE RECORDER, AND THE BLACK BULB THERMOMETER

By H. L. WRIGHT, M.A.

Introduction.—The Gorczynski pyrheliometer is an instrument which is designed to give continuous registration of the intensity of solar radiation. An instrument of this pattern was installed at Kew Observatory in 1926 and the records obtained from it during the period July to November, 1927, have been made the subject of review. Some of the results disclosed by the review are worthy of record and these are briefly stated in the present note*.

Intensity and duration of sunshine.—Comparison of the monthly totals of radiation with the monthly totals of sunshine duration showed that for every hour of sunshine the radiation received on a square centimetre of surface exposed normally to the sun amounted on the average to 35 gm. cal. The highest monthly average rate was 46 gm. cal. per hour in September, the lowest 25 gm. cal. per hour in November. During prolonged periods of continuous sunshine the highest hourly values of radiation were between 62 and 72 gm. cal./cm.^{2} in each of the months July to October. The time of occurrence of the highest values was early in the day, between 8h. and 11h., in July, August and September, and at midday in October. In November the highest hourly value was 37 gm. cal./cm.^{2}, from 14h. to 15h., but only six complete records exist for November.

The relation between the daily aggregate of radiation recorded by the Gorczynski instrument and the daily duration of sunshine registered by the Campbell-Stokes recorder is as shown in Fig. 1. Days when there was less than half an hour of sunshine are not represented on the diagram as the frequency of these is considerable and if they were included the congestion near the origin of co-ordinates would be excessive.

In seeking to interpret the diagram it is to be remembered that the estimates of duration ignore conditions of intensity. In measuring the Campbell-Stokes record equal value is given to sunshine from clear skies and to sunshine from hazy skies. The values of radiation recorded by the Gorczynski instrument are, on the other hand, considerably different in the two sets of conditions. The straight line drawn in Fig. 1 may therefore be taken to represent

* Readings from a Gorczynski pyrheliometer have been published since June 1930 in M. Volochine's *Bulletin Actinométrique International*. Similar readings are to appear in the *Observatories Year Book* for 1934 and onwards.

the relation between the daily duration and the daily aggregate of radiation at Kew Observatory under the most favourable conditions, that is, when atmospheric absorption is at a minimum. The curve drawn in the diagram represents average conditions and may be utilised for estimating the average amount of solar radiation to be expected for a specified duration of sunshine. The equation of the curve is

$$y = 20\ x^{4/3}$$

where y = gm. cal. of radiation per cm.^{2} of normal surface and x = number of hours of sunshine.

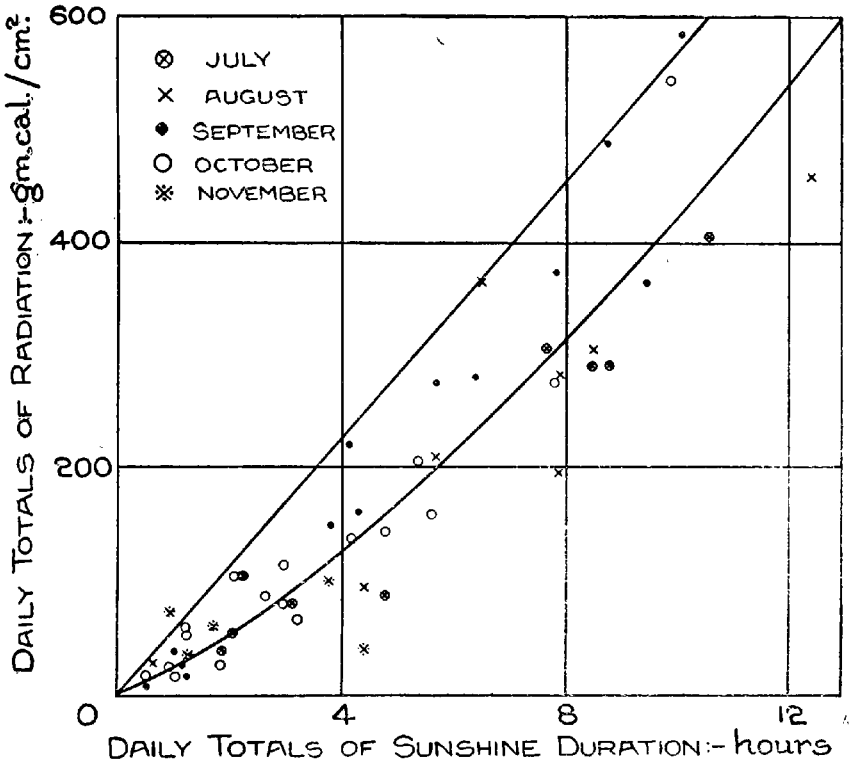

FIG. 1.

The rate of radiation corresponding to the slope of the straight line drawn in Fig. 1 is 0·95 gm. cal./cm.^{2} min., about half the solar constant. This is a mean rate averaged throughout the day, no allowance being made for the different values of the air mass in the path of a sunbeam at different times of day. It represents approximately the average daily rate at which radiation is received on a normal surface at Kew Observatory under the most favourable conditions.

The highest instantaneous rate of radiation recorded in the period under review was 1·43 gm. cal./cm.^{2} min. on September 24, 1927. This was in polar air behind a complex depression over the North Sea. The barometer reading at Kew (10m. above sea level) was 985 mb. and pressure was rising briskly.

Width of the burn on the sunshine card.—The scorched cards taken from a Campbell-Stokes recorder show burns which range from a faint streak barely perceptible to a band more than 3 mm. in width. The width of the burn depends principally upon the intensity of the radiation incident on the glass sphere if the composition of the material of which the cards are made is invariable. It ought, however, to be remarked that, the sunshine card being but an approximation to a spherical surface, the burning power of the sun's rays varies with the position of the sun's image on the card (and consequently with the time of year), being a maximum when the sun's image falls on the central line of the card. When equinoxial cards are in use, however, this effect is offset by there being a metal strip, about 5 mm. wide, behind the central line of the card. When the sun's image falls on a point backed by this strip some of the heat available for scorching the card is lost by conduction.

Comparison of the width of the burns on the sunshine cards with the rate of radiation recorded simultaneously by the Gorczynski instrument showed that generally speaking radiation at a rate of 0·2 gm. cal./cm.^{2} min. or less is not sufficient to burn the card. Instances were found, however, in which a rate of as much as 0·5 proved inadequate. All of these exceptional cases occurred in the early morning at sunrise and it is well known that in summer at sunrise and sunset the shadow of the bowl falls on the glass sphere and reduces the amount of radiation available for scorching the card. On one occasion a faint burn 1 mm. in width was found to correspond with a rate of radiation equal to 0·25 gm. cal./cm.^{2} min. An intensity of this order seems to be the minimum which will be registered on the sunshine card and the width of the resulting burn may be anything between 0·1 and 0·5 mm. Intensities of this order occur most frequently shortly after sunrise or before sunset but not exclusively at these times.

The mean rates of radiation associated with burns of specified width are shown diagrammatically in Fig. 2. The assumption of an exponential relation between the rate of radiation and the width of the burn gives a correlation coefficient of 0·97 and the formula connecting the two quantities is found to be

$$z = 0 \cdot 18\, e^{0 \cdot 64\, w}$$

where z denotes the number of gm. cal. received per sq. cm. of normal surface per minute, and w denotes the width of the burn in mm.

The graph of this equation is drawn in Fig. 2. The value of z when $w = 0$ agrees well with the rough estimate of the threshold

value stated above as being of the order of 0·2 gm. cal./cm.^{2} min. While the formula just given cannot be applied with much confidence to individual observations it may be expected to give accurate results as applied to the average of a number of observations.

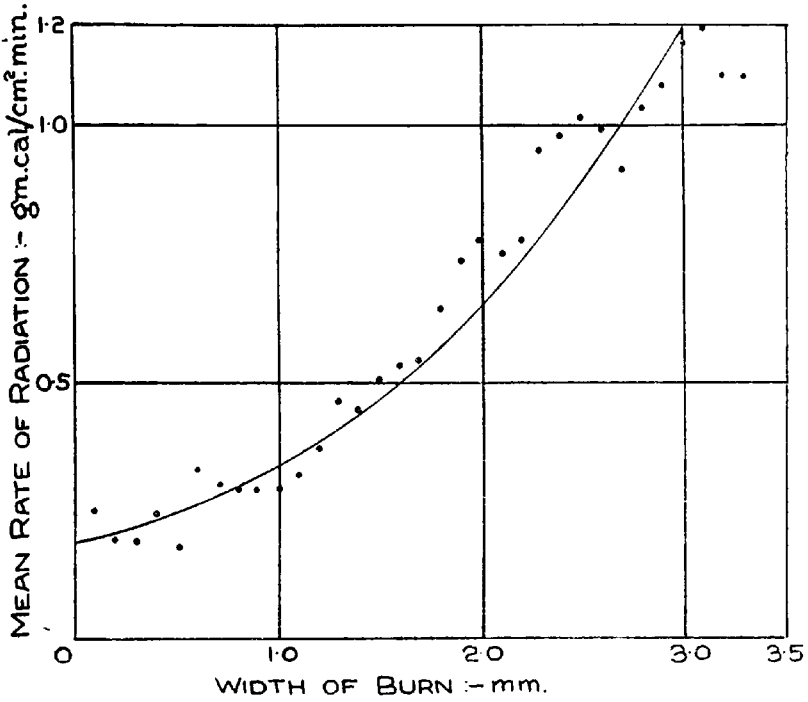

FIG. 2.—COMPARISON BETWEEN THE WIDTH OF THE BURN ON THE SUNSHINE CARD AND THE ASSOCIATED RATE OF RADIATION.

The black bulb thermometer.—The interpretation to be placed upon readings of a black bulb thermometer in vacuo is generally admitted to be obscure. Ultimately the readings are only of value if they can be interpreted in terms of radiation and at present this cannot be effected as the presence of the glass cover and uncertainties as to the condition of the black coating over the bulb and of the vacuum, both of which are liable to deteriorate, introduce complications the effect of which is beyond estimate.

The Gorczynski records afford a means of comparing the daily readings of the black bulb thermometer with the maximum rate of radiation registered each day by the pyrheliometer. These two quantities are plotted one against the other as shown in the left-hand diagram of Fig. 3. In the right-hand diagram values of the maximum rate of radiation are plotted against D, the difference between the black bulb reading and the reading of the maximum thermometer in the Stevenson screen.

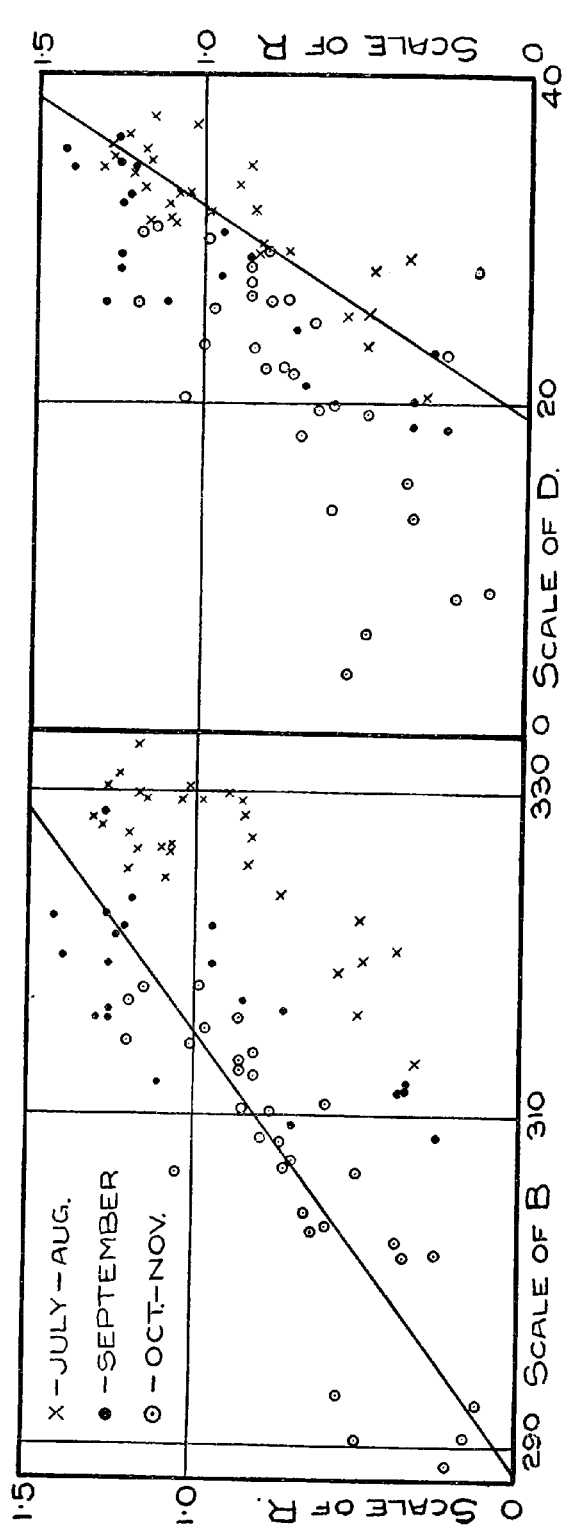

FIG. 3

The equations of the straight lines drawn in the diagrams are $R=\frac{1}{25}(B-289)$ and $R=\frac{1}{13}(D-19)$.

R = Daily maximum rate of radiation : gm. cal./cm.^{2} min.
B = " " reading of black bulb thermometer (°A).
D = Difference between the daily maximum reading of the black bulb thermometer and the daily maximum reading of the screen thermometer °A.

It is evident from the diagrams that the relation between the black bulb reading and the rate of radiation varies with the time of year. In both diagrams there is considerable scatter but for the July and August readings the diagram on the right shows less scatter than that on the left and a straight line may be drawn, as shown in the figure, about which the plotted points are reasonably closely distributed. For October and November the scatter is less in the left-hand diagram and the straight line drawn therein is, apart from three isolated cases, a fair approximation to the array of points for the months named. In September high readings approximate to the October–November distribution while low readings approximate to the July–August distribution.

The equations of the straight lines drawn in the diagram are as follows :—

July–August $R = \frac{1}{13}(D - 19)$

October–November $R = \frac{1}{26}(B - 289)$

where R denotes the daily maximum rate of radiation (gm. cal./min. per cm.^{2} of normal surface), B the daily maximum reading of the black bulb thermometer (°A) and D the difference between the black bulb reading and the reading of the maximum thermometer in the Stevenson Screen (°A).

For the most part the error of individual values of R computed from the formulæ is less than 0·3 gm. cal./cm.^{2} min. Care must, however, be exercised in applying these formulæ generally as the numerical coefficients may depend to an extent which cannot be stated on the coefficients of absorption of the particular black bulb thermometer in use at Kew Observatory.

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